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EI*"Transmission of Data in Boreholes"

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3 This invention relates to a method of and apparatus for
4 transmitting data in boreholes such as oil wells.

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6 To optimise the efficiency both of the detection of oil
7 reserves and the recovery of these reserves, it is
8 important to obtain as much detailed information as
9 possible about the ambient environmental conditions at
10 the base of an oil well. This information is obtained
11 by a variety of sensors located at the base of a well
12 when required. The information obtained by the sensors
13 may be transmitted to the surface of an open well using
14 sonic waves which propagate through the drilling mud.

15

16 However, this method may only be employed during
17 drilling when sufficient hydraulic power is available
18 to generate the signal at the base of the well. During
19 well testing and production this power source is not
20 available and a valve or plug may be inserted in the
21 well resulting in there being no direct fluid path
22 through the centre of the well from the base of the
23 well to the surface.

24

25 One situation to which this particularly applies is in

1 shut-in testing where a shut-in valve is included in
2 the well. A test generally consists of flowing the
3 well, thus drawing down the well pressure, and then
4 suddenly stopping the flow by closing the shut-in
5 valve. Information regarding the potential of the
6 reservoir can be derived from examination of the
7 ensuing pressure rise/time characteristic, requiring a
8 pressure gauge beneath the valve. The shut-in is best
9 done down-hole rather than at the surface, to avoid
10 well-bore storage effects which are difficult to
11 compensate for.

12
13 It is possible to adapt valves to produce a hydraulic
14 or electrical path through the valve to enable the
15 transmission of signals from a sensor below the valve
16 to a receiver above the valve. The path through the
17 valve terminates in a connector which is suitable for
18 connection to the receiver, the receiver in turn being
19 connected via a cable to the surface of the well.
20 However, this system is extremely difficult to operate
21 as the small connector on the surface of the valve is
22 extremely difficult to contact with the receiver and a
23 considerable length of time is taken to make a suitable
24 connection.

25
26 Accordingly, the present invention provides a method of
27 transmitting data in a borehole, the method comprising
28 providing an electric signal representative of the data
29 to be transmitted, converting said electric signal into
30 a sonic signal, propagating said sonic signal along an
31 elongate member, and processing the sonic signal for
32 onward transmission.

33
34 The processing of the sonic signal may for example be
35 at the surface, or it may be downhole by retransmission

1 or it may be by electronic data storage for later
2 pick-up.

4 In another aspect, the invention provides apparatus for
5 transmitting data in a borehole, the apparatus
6 comprising a transmitter and a receiver; the
7 transmitter including means for converting data
8 parameters into an electric signal and first transducer
9 means responsive to said electric signal to generate an
10 acoustic signal, the first transducer means being
11 adapted for physical coupling to an elongate member
12 extending along the borehole whereby the acoustic
13 signal is propagated in said elongate member; the
14 receiver comprising second transducer means adapted for
15 physical coupling to said elongate member to produce an
16 electrical output corresponding to said acoustic
17 signal, and signal processing means connected to
18 receive said output and operative to process the data
19 into a condition for onward transmission.

20
21 An embodiment of the invention will now be described,
22 by way of example only, with reference to the drawings,
23 in which:

24
25 Fig. 1 is a schematic cross-sectional side
26 view of apparatus in accordance with the
27 invention in use in a well;

28 Fig. 2 is a block diagram of a transmitter
29 forming part of Fig. 1;

30 Fig. 3 is a block diagram of a receiver
31 forming part of Fig. 1; and

32 Fig. 4 is a block diagram of an alternative
33 form of receiver.

34
35 Referring to Fig. 1, a drill stem 1 is sealed to a well

1 bore 23 by a packer 2, leaving an annulus 3 to contain
2 mud and well control fluid. Any production fluids will
3 pass up the centre of the drill stem 1 via a shut-in
4 valve 4. The present embodiment utilises the invention
5 to pass data relating to the fluid pressure in the
6 drill stem bore 24 below the shut-in valve 4 to a
7 location above it.

8
9 A transmitter designated generally at 6 is positioned
10 in an external recess 25 of the drill stem 1. The
11 transmitter 6 is powered by a battery 7 and includes a
12 pressure transducer 9 communicating with a lower bore
13 24 via a port 8. The analog pressure signal generated
14 by the transducer 9 passes to an electronics module 10
15 in which it is digitised and serially encoded for
16 transmission by a carrier frequency, suitably of 2-10
17 kHz. The resulting bursts of carrier are applied to a
18 magnetostrictive transducer 11 comprising a coil formed
19 around a core whose ends are rigidly fixed to the drill
20 stem 1 at axially spaced locations. The digitally
21 coded data is thus transformed into a longitudinal
22 sonic wave in the drill stem 1.

23
24 A receiver generally designated at 12 is housed in an
25 external recess 26 of the drill stem 1 at a location
26 above the shut-in valve 4. The receiver 12 comprises a
27 filter 13 and transducer 14 connected to an electronics
28 module 15 powered by a battery 17.

29
30 The output of the electronics module 15 drives a signal
31 coil 16.

32
33 The filter 13 is a mechanical band-pass filter tuned to
34 the data carrier frequency, and serves to remove some
35 of the acoustic noise in the drill stem 1 which could

1 otherwise swamp the electronics. The transducer 14 is
2 a piezoelectric element. The filter 13 and transducer
3 14 are mechanically coupled in series, and the
4 combination is rigidly mounted at its ends to the drill
5 stem 1, aligned with the longitudinal axis of the
6 latter. Thus, the transducer 14 provides an electrical
7 output representative of the sonic data signal.

8
9 A preferred method of retrieving the data is to store
10 it in memory in the electronics module 15, for
11 retrieval at a convenient time by a pick-up tool 5.
12 This avoids the problems inherent in providing a
13 real-time data path along the whole length of the well.
14 The pick-up tool 5 is lowered on a cable or wireline 22
15 to locate in a nipple 18 which causes the signal in the
16 receiver 16 to be aligned with a coil 19 in the pick-up
17 tool 5. The coils 16 and 19 are then inductively
18 coupled, allowing the data to be transferred to the
19 pick-up tool 5 serially on a suitable carrier wave to
20 the pick-up tool 5.

21
22 The pick-up tool 5 includes an electronics package 20
23 which is arranged to send a transmit command to the
24 receiver 12 when the tool 5 is seated on the nipple 18.
25 The electronics package 20 may be arranged to decode
26 and store the data if the tool is on wireline, or to
27 re-transmit the data if the tool is on cable. In the
28 latter case, power may be supplied to the tool via the
29 cable; otherwise, power is derived from an internal
30 battery 21.

31
32 Referring now to Fig. 2, the transmitter electronics
33 module 10 in the present embodiment comprises a signal
34 conditioning circuit 30, a digitising and encoding
35 circuit 31, and a current driver 32. The details of

1 these circuits do not form part of the present
2 invention, and suitable circuitry will be readily
3 apparent to those skilled in the art. The transducer
4 11 has a coil 33 connected to the current driver 32 and
5 formed round a core schematically indicated at 34.
6 Suitably, the core is a laminated rod of nickel of
7 about 25 mm diameter. The length of the rod is chosen
8 to suit the desired sonic frequency which is suitably
9 in the range 100 Hz to 10kHz, preferably 2-6 kHz.

10

11 In the receiver, as seen in Fig. 3, the electronics
12 module 15 comprises in series a passive band-pass
13 filter 35, an active band-pass filter 36, and a
14 phase-locked loop 37 supplying clean data signals to a
15 decoder 38. The decoded data is stored in memory 39.
16 When a pick-up tool 5 is positioned and activated,
17 carrier frequency induced in the signal coil 16 is
18 detected at 40 to enable control logic 41 to read data
19 from memory 39 for transmission via encoder 42, current
20 driver 43, and the signal coil 16.

21

22 The alternative receiver shown in Fig. 4 uses a similar
23 mechanical filter 13, transducer 14, and electronic
24 filters 35 and 36. In this case, however, the filtered
25 data signal is not stored but is used to control a
26 current driver 44 driving a magnetostrictive transducer
27 45 for sonic re-transmission further along the drill
28 stem.

29

30 Thus, the invention enables data to be transferred by
31 sonic transmission past a valve or the like and then
32 further handled by (a) storage in memory for later
33 retrieval, (b) real-time transmission electrically by
34 cable, or (c) sonic re-transmission.

35

1 Modifications may be made within the scope of the
2 invention. For example, the transmitter transducer may
3 impart a torsional, rather than a longitudinal, sonic
4 vibration to the drill stem. Transducers of other than
5 magnetostrictive type may be used, such as
6 piezoelectric crystals or polymers.

7

8 Although described with particular reference to shut-in
9 testing in producing wells, the invention may be
10 applied to any situation where a borehole is
11 obstructed. The medium for sonic transmission need not
12 be a drill stem but could, for instance, be casing or
13 other tubular.

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1. A method of transmitting data in a borehole, the method comprising providing an electric signal representative of the data to be transmitted, converting said electric signal into a sonic signal and propagating said sonic signal along an elongate member, said data being transmitted from one side to the other of a physical obstruction in said elongate member, the conversion of the electric signal into the sonic signal being effected at a location on said one side; characterised in that said sonic signal is converted into an electrical signal on said other side of said obstruction and said data is stored on said other side for subsequent retrieval.

2. A method according to claim 1, in which the subsequent retrieval is effected by a pick-up tool lowered down the borehole to a location adjacent the obstruction.

3. A method according to claim 1, in which conversion from the electric signal to the sonic signal includes digital modulation of a carrier frequency in the range 100 Hz to 10 kHz.

4. A method according to claim 1, in which the sonic transmission is effected by longitudinal vibration.

5. A method according to claim 1, in which the elongate member is a drill stem, the obstruction is a shut-in valve in the drill stem, and the data

1 comprises pressure-versus-time in the drill stem
2 beneath the shut-in valve.

3
4 6. Apparatus for transmitting data in a borehole, the
5 apparatus comprising a transmitter and a receiver;
6 the transmitter including means for converting
7 data parameters into an electric signal and first
8 transducer means responsive to said electric
9 signal to generate an acoustic signal, the first
10 transducer means being adapted for physical
11 coupling to an elongate member extending along the
12 borehole whereby the acoustic signal is propagated
13 in said elongate member; the receiver comprising
14 second transducer means adapted for physical
15 coupling to said elongate member to produce an
16 electrical output corresponding to said acoustic
17 signal, and signal processing means connected to
18 receive said output and operative to process the
19 data into a condition for onward transmission;
20 characterised in that said signal processing means
21 includes memory means for storing received data,
22 and means for transferring data from the memory
23 means to a pick-up tool lowered to an adjacent
24 location in the borehole.

25
26 7. Apparatus according to claim 6 for use in
27 transmitting data from one side to the other of an
28 obstruction in said elongate member, the first
29 transducer means being coupled, in use, to the
30 elongate member at a location on said one side of
31 the obstruction, and the second transducer means
32 being coupled, in use, to the elongate member at
33 the other side of the obstruction.

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- 1 8. Apparatus according to claim 6, in which the first
2 transducer means is a magnetostrictive transducer
3 adapted to be mounted to the elongate member to
4 produce longitudinal sonic vibrations in it.
5
6 9. Apparatus according to claim 7, in which the data
7 parameter converting means is a fluid pressure
8 transducer for monitoring fluid pressure below
9 said obstruction.
10
11 10. Apparatus according to claim 6, in which said
12 second transducer means comprises a mechanical
13 bandpass filter and a piezoactive element mounted
14 in series on the elongate member.
15
16 11. Apparatus according to claim 6, in which the
17 signal processing means includes electronic filter
18 means.
19
20 12. Apparatus according to claim 6, in which the
21 pick-up tool includes further memory means in
22 which the data may be stored until the pick-up
23 tool is returned to the surface.
24
25 13. Apparatus according to claim 6, in which the
26 pick-up tool includes means for transmitting the
27 data to the surface via a cable.
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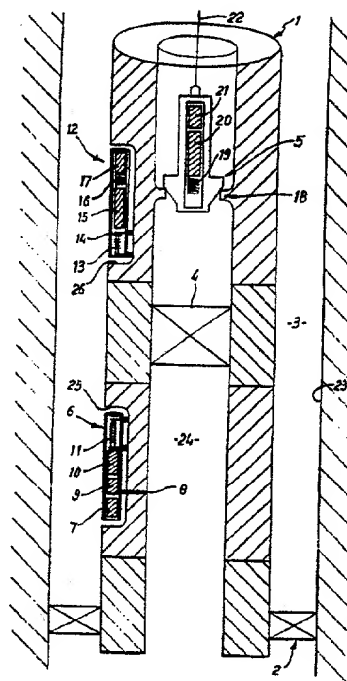
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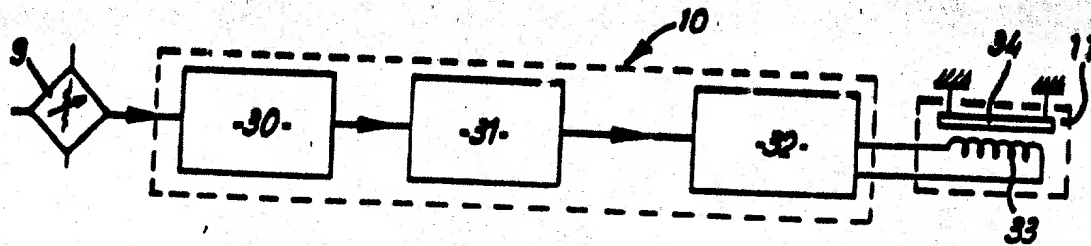
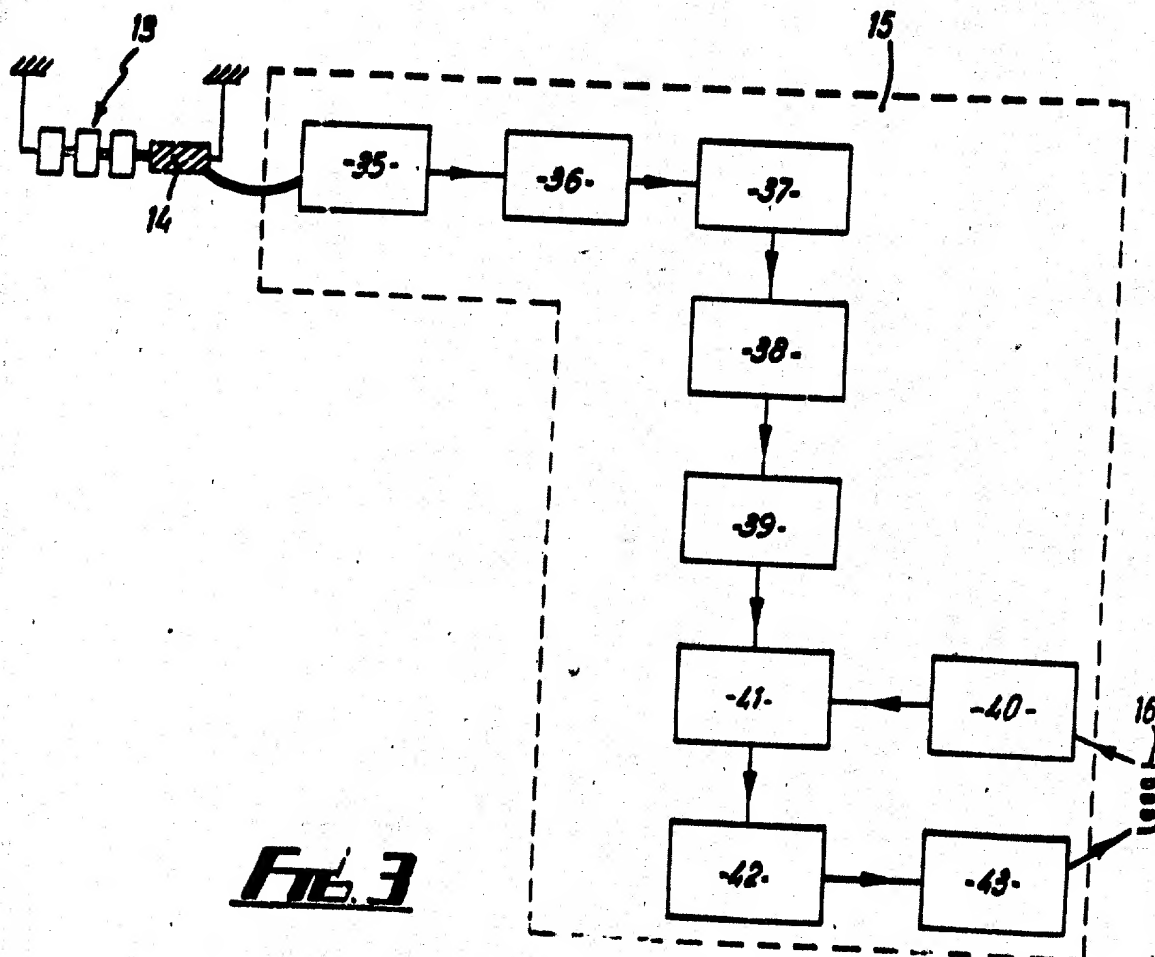
(54) Title: TRANSMISSION OF DATA IN BOREHOLES

(57) Abstract

Data is transmitted along a borehole containing a drill stem (2) by means of a transmitter (6) which converts electric data signals to acoustic signals propagating along the drill stem (2). The acoustic signals are converted back to electric form by a receiver (12) which also processes the signals. In the preferred form the signals are stored in a receiver memory (15) for subsequent retrieval using a pick-up tool (5) lowered into the borehole. The system is particularly useful in moving data past an obstruction such as a shut-in valve (4).



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**FIG. 2****FIG. 3**

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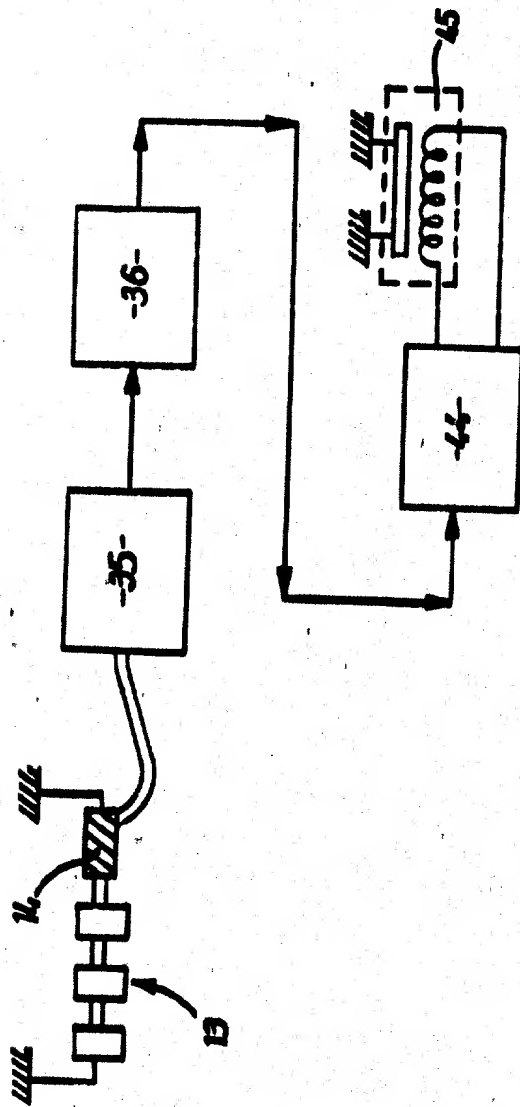


Fig 4

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